

1 **"GAS LIFT APPARATUS FOR A WELL"**

2 **FIELD OF THE INVENTION**

3 The present invention relates to apparatus for use in a flowing natural gas well
4 to assist with gas lifting water, co-produced with the gas, to ground surface.

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6 **BACKGROUND OF THE INVENTION**

7 The present invention was conceived to address problems affecting natural gas
8 recovery from wells in the southern gas fields of Saskatchewan. The problems will be
9 described in connection with those wells. However it will be appreciated that the
10 invention may find application in other fields and wells.

11 The subterranean gas producing reservoir or formation involved is at shallow
12 depth (about 340 – 695 feet). The wells are flowing wells. In a typical case, each
13 well is cased with a string of 4" tubular production casing to total depth and is
14 perforated across a production interval of the formation. A string of 3/4" to 1-1/4"
15 tubular continuous coil tubing extends down to the perforations. Some of the tubing
16 strings are equipped with a packer. The packer seals against the casing to sub-divide
17 the annulus between the two strings at a point above but close to the perforations.

18 In most wells, the producing formation produces salt water and particulate
19 solids along with the natural gas.

20 The water is lifted by the gas up through the bore of the tubing string to
21 ground surface in the form of alternating slugs of gas and water, under the impetus of
22 formation pressure. However, slugs of water may settle in the tubing string and
23 coalesce to form a column. This column may have a hydrostatic head that equals or
24 exceeds the bottom hole pressure. In this event, the well will 'die'. That is, additional

1 fluid will be unable to enter the casing bore and fluid production from the well will
2 cease.

3 The entry of particulate solids, such as sand, into the casing bore creates a
4 different problem. The solids may settle in the annulus and build up at the base of the
5 well until they cover the perforations, thereby interfering with incoming fluid flow
6 from the formation.

7 It therefore is desirable to provide means for enhancing gas lift in the tubing
8 string, with the aim of reducing settling and coalescence of the water slugs being
9 produced.

10 It preferably also is desirable to enhance the turbulence of flow at the base of
11 the casing bore, with the aim of reducing settling and build up of solids.

12 13 **SUMMARY OF THE INVENTION**

14 In accordance with one embodiment of the invention, a flowing gas well is
15 provided, having a string of production casing and a string of production tubing. The
16 casing string is perforated across a production interval of the producing formation.

17 A funnel, preferably conical in configuration, forms the lower end of the
18 tubing string.

19 The funnel widens downwardly to approach the inside surface of the casing
20 string. The internal, longitudinal passageway of the funnel and the longitudinal bore
21 of the tubing string combine to form an open-bottomed production bore.

22 The casing and tubing strings form an annulus therebetween.

1 A packer is mounted on the tubing string above the funnel. The packer
2 functions to seal against the casing string to isolate the lower portion of the annulus
3 beneath the packer from the upper portion of the annulus above the packer.

4 The tubing string, packer and funnel combine to form a structural unit.

5 A tube, supported by the structural unit, connects the lower portion of the
6 annulus with the production bore. More particularly, the tube has an inlet that
7 communicates with the upper end of the lower portion of the annulus and an upwardly
8 directed outlet that communicates with the production bore. Preferably the outlet is a
9 restrictive orifice.

10 In use, the bottom of the funnel is preferably positioned close to and above the
11 perforations. Produced water will accumulate in the bottom of the casing bore and
12 will rise to cover the base of the funnel side wall. Gas separates from the water in the
13 casing bore and rises to accumulate as a column in the annulus, extending down from
14 the packer. As gas pressure in the lower portion of the annulus increases, water above
15 the bottom rim of the funnel is displaced into the production bore, where it joins water
16 and gas that have traveled from the perforations into the production bore. The flow of
17 water and gas passing through the narrowing funnel passageway accelerates, has
18 increasing turbulence and tends to hold contained solids in suspension. At the same
19 time, gas under pressure flows from the upper end of the lower portion of annulus,
20 through the tube bore, and is discharged as a jet into the production bore. This gas
21 functions to assist in gas lifting water through the production bore to ground surface.
22 The gas and water rise through the production bore in the form of discrete slugs.

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1 Broadly stated, the invention comprises an apparatus for assisting in producing
2 gas and water to ground surface from a subterranean formation through a flowing well
3 having a tubular production casing string forming a longitudinal bore and having
4 perforations in fluid communication with the formation, comprising: a tubular
5 production tubing string forming a longitudinal bore and extending down the casing
6 string from ground surface; a funnel forming the lower end of the tubing string, the
7 funnel having a bottom inlet and a longitudinal passageway extending therethrough;
8 the tubing string bore and the funnel passageway combining to form a production
9 bore; the casing and tubing strings forming an annulus therebetween; packer means,
10 mounted on the tubing string above the funnel, for sealing against the casing string to
11 isolate the lower portion of the annulus beneath the packer means from the upper
12 portion of the annulus above the packer means; the tubing string, funnel and packer
13 means combining to form a structural unit; and a tube, carried by the unit, having an
14 inlet communicating with the annulus lower portion and an upwardly directed outlet
15 communicating with the production bore; so that, in use, gas separates and
16 accumulates as a column beneath the packer in the annulus lower portion and
17 displaces water from said annulus lower portion into the production bore and gas
18 travels from the column through the tube and is discharged upwardly into the
19 production bore for gas-lifting water to ground surface through the production bore.

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DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic side view, in simplified form, showing a flowing gas well in accordance with the prior art;

Figure 2 is a schematic side view similar to Figure 1, showing a flowing gas well incorporating one embodiment of the present gas lift apparatus; and

Figure 3 is an expanded schematic side view of the gas lift assembly of Figure 2, showing the production casing and tubing strings, a packer, a funnel and a gas transfer tube.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Having reference to Figure 2, there is provided a conventional flowing gas well 1 for producing gas 2 and salt water 3 from a subterranean formation 4.

A string 5 of production casing extends down from the wellhead 101 at ground surface 6 and penetrates the formation 4. The casing string 5 is perforated across a formation interval by perforations 7, to enable fluids to enter the casing bore 10 from the formation 4.

A string 9 of continuous coil tubing extends down the bore 10 of the casing string 5 from ground surface 6. The tubing string 9 is landed above but close to the perforations 7.

A conventional packer 15, used with continuous coil tubing, is mounted on the lower end of the tubing string 9. The packer 15 seals against the inside surface 16 of the casing string 5 at a point spaced above the perforations 7. The packer 15 isolates the lower portion 17 of the annulus 18, formed between the casing and tubing strings 5, 9, from the upper portion 19 thereof.

1 A funnel 20 is attached at its upper end to the lower end of the tubing string 9.
2 The funnel 20 widens downwardly, so that its bottom edge 21 is close to but spaced
3 from the inside surface 16 of the casing string 5. The funnel 20 forms an internal
4 longitudinal passageway 22 extending therethrough. The passageway 22 combines
5 with the tubing string bore 100 to form an open-bottomed production bore 23.

6 The tubing string 9, packer 15 and funnel 20 combine to form a structural unit
7 24.

8 A tube 30 is supported by the unit 24. The tube 30 has an inlet 31, a
9 longitudinal bore 32 and an outlet 33. The inlet 31 communicates with the lower
10 portion 17 of the annulus 18, directly beneath the bottom end of the packer 15. The
11 tube outlet 33 communicates with the production bore 23. The outlet 33 preferably is
12 a restrictive orifice. In the specific embodiment shown, the tube 30 extends upwardly
13 through the body 34 of the packer 15, bends through 180°, extends back down through
14 the packer body and through the side wall 35 of the funnel 20 and then bends again,
15 so that its outlet 33 is upwardly directed in the funnel passageway 22.

16 The assembly of the tubing string 9, packer 15, funnel 20 and tube 30, when
17 positioned within the casing string 5 of a gas well 1, provides an apparatus for
18 producing gas and water.

19 In operation, gas 2 and water 3 enter the bottom of the casing string bore 10
20 through the perforations 7. Gas 2 breaks out of the mixture, rises and accumulates as
21 a short column 36 in the lower portion 17 of the annulus 18, directly beneath the
22 packer 15. The mixture of water and gas in the casing string bore 10 forms a column
23 37 that covers the bottom edge 21 of the funnel 20. Formation pressure drives water
24 and gas up into the production bore 23. As the gas pressure of the annular column 36

1 builds up, it tends to force water, covering the bottom end of the funnel 20 into the
2 production bore 23. The diminishing cross-section of the funnel passageway 22 tends
3 to accelerate the flow moving therethrough. At the same time, gas from the column
4 36 moves through the tube bore 32, under pressure, and is discharged as an upwardly
5 directed jet through the outlet 33 into the production bore 23.

6 Experimental runs with laboratory scale equipment have indicated that
7 conveying gas from the lower portion of the annulus and discharging it as an
8 upwardly directed jet into the production bore, is of assistance in gas lifting water to
9 ground surface through the production bore.

10 It is anticipated that those skilled in the art can substitute equivalents or
11 variants for the components of the assembly, without significantly altering the manner
12 in which the assembly works. For example, various forms of packer may be used.
13 The funnel may be conical or stepped in configuration. The tube does not need to
14 extend up and back down through the packer – it can have its inlet positioned in the
15 annulus lower portion and extend directly through the funnel side wall into the
16 production bore. The scope of the invention is defined by the claims now following
17 and is intended to cover variants.

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